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HALE
ON
PROPELLING
VESSELS

TREATISE

ON

PROPULSION BY STEAM POWER.

LONDON: PRINTED BY
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TREATISE

ON THE

MECHANICAL MEANS BY WHICH VESSELS ARE PROPELLED BY STEAM POWER.

BY WILLIAM HALE, C.E.

LONDON:
LONGMANS, GREEN, AND CO.
1868.

186. e. 24.

PREFACE.

In past ages, the light of science was communicated only to a few, but the present is an epoch remarkable for a great influx of light, and the progress of improvement in science and art is comparatively little impeded by the ignorant prejudice which formerly resisted every innovation.

The amazing discoveries that have been made in chemistry, and the various mechanical inventions that have been devised, especially within the last few years, constitute a study worthy of the most intelligent minds; not only from the great interest attaching to them on their own account, but also from the question they suggest, as to their ultimate effect upon the welfare of mankind.

Within this century their effect has been so great, that the present condition of the world, as contrasted with former periods of its history, may be compared to the dawn of day breaking forth from the obscurity of night. So widely and so rapidly is knowledge being diffused, that on all

sides, we are reminded, that the night of ignorance is passing away, and we may anticipate, that discovery and invention which have already revealed such wonders, will yet make manifest others which would in our forefathers' time have been deemed impossible, without an alteration in the natural laws and constitution of things.

The system of locomotion, especially, is now so changed, that a multitude of people can travel by land more rapidly, and with greater ease and comfort, from one country to another, than a few could formerly from county to county. The speed to be attained in travelling, as also the weight to be transported, were limited by, and wholly dependent on, the capabilities and endurance of the horse; but now that noble animal's power is superseded by the mighty agency of steam, which, in the speed to be obtained and the weight to be carried, is hardly to be limited. More than a thousand passengers can now be conveyed in one train, with a velocity equalling that of the flight of the swiftest bird; while the weightiest masses of goods, &c., can be transported with similar speed.

Roads are not now, as formerly, constructed of earth and rough stones, but of smooth iron, made straight and level as a plain. Valleys are raised, and mountains and hills made low; and a pathway is being opened everywhere, for the more complete

diffusion of knowledge, and spread of the arts of civilisation over the whole earth.

The necessity no longer exists, as aforetime, of ships waiting for a favourable wind, or being delayed by traverse sailing; but in defiance of the wind, by the wonder-working power of steam, the largest vessels are now propelled in a straight course from one hemisphere to the other, with greater certainty and speed, than could ever have been attained by the wind, even when most powerful and direct; and this without the fear of being driven back, or wrecked upon a lee shore.

When steam power was first introduced for impelling vessels, paddle-wheels only were employed as a mechanical agent to render the power effective, and afterwards the screw was used as a substitute for paddle-wheels, the writer being the first, as he believes, who used the screw in this country, for that purpose. He commenced a patent for propeling by two screws, one on either side of the stern-post; but being informed by the Patent Agent, just before the expiration of the time allowed by law for enrolling the specification, that the screw had been publicly used at the stern for propelling boats, in America, he abandoned his idea of using the screw outside and confined himself, in his specification, to employ the screw inside a cylinder, fixed inside the vessel; as may be seen

by reference to his Patent, dated 22nd September, 1827. Sufficient success was obtained by this plan to induce the writer to follow up the idea of propelling by the force of streams of water, and in consequence he took out several patents for propelling vessels by this means.

The subjective matter of the following pages will show, that the writer still retains the idea of propelling by volumes of water, in preference to paddle-wheels or screw-propellers, both for safety and propelling effect. In the treatise itself, many imperfections will doubtless be found, and, from the very nature of the subject, tautologies are not easily to be avoided. The writer seeks, in his remarks, to clothe his ideas in the plainest language, without aspiring to elegance of diction; and if he has been fortunate enough to make himself readily understood, his end is answered.

LONDON:

6th April, 1868.

TREATISE,

&c.

THE SUBJECT of propelling vessels has for many years occupied the attention of most mechanical philosophers, and particularly engineers, but with comparatively little result, except in the construction of compact, powerful engines for exerting great power upon the direct propelling agent: with the exception of such improvements—and they have been considerable—little or nothing has been done, in improving the mode of propulsion.

As the following pages are intended to correct some popular errors on this subject, as well as to bring before the public a new propelling agent, we beg to solicit of all persons interested, a fair and candid investigation, and in doing so trust that no one will endorse the opinions of others, however eminent in science, without being convinced by his own judgment, that the opinions he forms are consistent with the true principles of mechanical science.

Before beginning to treat on the primary object in view, we will endeavour to point out an error which has wormed its way into the works of eminent writers on mechanics, viz. that the oar used

to propel a boat is a lever of the second order, whereas it will, we believe, appear evident—from what is herein advanced—that the oar is a lever of the first order. We bring this case forward simply to show that persons capable of judging ought not to be guided even by eminent men, without carefully reflecting for themselves, otherwise errors may be propagated for ages, and false conclusions stand for truths, to the great detriment of science.

With due deference to those from whom we differ on the point just alluded to, we will endeavour to prove that the oar is not a lever of the second order, but that it is one of the first order.

Dr. Hutton defines a lever to be '*a straight bar* '*of iron or wood, &c., supposed to be inflexible, sup-* '*ported on a fulcrum or prop by a single point,* '*about which all the parts are movable.*' He also defines a fulcrum to be '*the fixed point about which* '*a lever turns and moves.*' Accepting these definitions, which there can be no doubt are perfectly correct, let it be observed, that a straight inflexible bar, simply of itself, is not a lever without the use of a fulcrum, and also that there are two essential characteristics that belong to a fulcrum. In the first place, the fulcrum must be immovable in relation to the lever, and is the centre on or about which the lever moves, describing an arc on both sides of the fulcrum. Second, the fulcrum always sustains double the weight of the body raised. Now, if this be true respecting the character of

a fulcrum, we will examine the case of a man rowing in a boat, upon these principles. As a matter of fact, the thole is the centre about which the oar moves, describing an arc on each side; and in relation to the oar, the thole always remains immovable, the power exerted by the man is at one end of the oar, and at the opposite end is the resistance offered by the water to the power exerted by the man; and in proportion to the quantity of resistance offered by the water—which gives way by the action of the oar in the same ratio as the oar is moved—the man must exert a moving force by pulling, while he moves his body, to keep up a pressure upon the resisting water. It is also a fact, that the thole sustains unyielding the pull of the man at one end of the oar, and the resistance offered by the water at the other end. Now, as both these forces bear upon the thole, the properties of a fulcrum belong to the thole, and not to the resistance of the water moved. With this mechanical arrangement, the effect upon the boat is to urge it forward, by the power of the man on one side of the thole and the resistance of the water to the action of the oar on the other side, and these forces react both in the same direction. It must, however, be borne in mind, that the man exerts as much force with his feet against the boat, in a contrary direction to that which he exerts upon the thole, and does thereby neutralise half the pressure against the thole, so that but one-

half of the entire pressure against the thole remains to urge the boat forward. This, we presume, is the cause and amount of force in giving the boat motion.

To make the oar a lever of the second order, it would be necessary to employ it after the following manner, that is to say: suppose a pile driven through the water firmly into the ground, with a pin on the top of the pile for a fulcrum, and a man in the boat places his oar against the thole, with one end of the oar against the immovable pin on the pile, and at the other end exerting his power to move the boat. The oar, in this case, would be a lever of the second order; but the only tendency of the force exerted by the man, would be to move the boat round the pile in a circle, the radius of which would be the length of the oar between the thole and the pin on the pile, which we will suppose to be two-thirds the length of the oar, and the radius of the circle described by the man in the boat would be the entire length of the oar. In the case now given, the effect of the man's force in giving motion to the boat, would be: that, as the power of the man is exerted upon the thole, at one-third longer leverage, the pressure against the thole would be one-third more than the force exerted by the man, and this force against the thole would have the tendency to urge the boat forward, not in a straight line, but in a circle round the pile; the amount of force exerted by the

man would, however, have to be deducted from the amount of pressure against the thole, because the man, at the same time that he is exerting his power upon the oar, presses with the same amount of force with his feet upon the boat, to move it in a contrary direction; consequently but one-third of the power exerted by the man would be effective to move the boat in a circle, described by the oar at the thole. This, we presume, would be the result of the oar being made a lever of the second order.

To illustrate more fully the effect of the oar upon a boat, when it is really constituted to be a lever of the second order: imagine a pile to be driven on each side of the bank of a canal, and a pin on the top of each pile to act as a fulcrum. If a man in a boat employs two oars, which he places against the pins as centres or fulcrums, and also against the tholes on each side of the boat, for urging the boat forward, the boat, we contend, would never be moved by such means, and whatever power the man might exert, the whole would be entirely lost for purposes of propulsion; because the power of the man would be exerted in two opposite directions, that is, one oar would have the tendency to turn the boat round one pile, and the other oar to turn the boat round the other pile, and these directions being contrary the one to the other, the two forces would neutralise each other, and the boat have no motion.

We consider the reasons herein stated constitute

the oar, as used by a man in rowing, to be a lever of the first order, and that it is an error to call it a lever of the second order. We can only account for such learned authorities as Dr. Hutton, Dr. O'Gregory, Dr. Arnot, and other eminent writers on mechanics, having inconsiderately propagated this error in their writings, by supposing, that as the boat is actually moved by the power of the man at one end of the oar, while bearing upon the thole which moves with the boat, they have hastily concluded, that the water against which the opposite end of the oar acts, is the fulcrum; this would be quite sufficient to account for the mistake, and it certainly is plausible, but nevertheless is very specious.

We will now proceed to remark upon another mistake, by which some persons, much interested in Steam Navigation, give evidence, that they are but superficially acquainted with the true principles of hydraulics, when they assert and maintain, respecting the propulsion of vessels, that as water is an unsubstantial body, the exercise of power for giving motion to a volume of water, which is to expend its force in water, must result in great loss and be far less efficient to propel vessels, than the same amount of power employed in giving motion to paddle-wheels, or screw-propellers; the fallacy of this notion we will also endeavour to prove.

It will not be disputed, that water is moved by

the least pressure when it is not confined, perhaps easier than any other matter; but when confined, it is not only found to be incompressible—as is proved by the hydrostatic bellows—but it is also found to be true, that when put in motion, and its whole momentum constrained to act but in one direction, no better agent can be employed for propelling bodies, or for giving impelling force to any kind of machinery.

There are three distinct modes by which water is rendered a faithful and efficient mechanical agent.

1st. By action or repulsion.
2nd. By pressure.
3rd. By reaction.

That by action, when the water is the moving power, as exemplified by water-mills; by pressure, shown by Dr. Barker's mill; and by reaction, as illustrated by paddle-wheels.

We will examine these three modes separately.

1st. A stream of water when acting with its whole momentum against the float-boards of a water-mill, always gives an impelling force, equal to the momentum of the stream, and no loss is sustained in consequence of water being in its nature unsubstantial.

2nd. To give an illustration of the action of water by pressure; suppose a square tank, capable of holding a quantity of water, say ten feet high,

and an aperture made on one side close to the bottom, of six inches diameter; the mouth of the aperture being formed to obviate any contracted vein and the tank constructed to run very easily on wheels; now, if the tank is supplied with water and constantly maintained to the height of nine feet nine inches above the mean height of the aperture, the water will flow from the aperture with a force equal to the weight of a column of water, whose base is six inches in diameter and its altitude nine feet nine inches; and this amount of weight, multiplied into the velocity a heavy body would acquire in falling through a space of nine feet nine inches, would give the quantity of motion or momentum of the flowing stream. The effect upon the tank would be, to move it in a contrary direction to the motion of the rushing water, with a force equal to the weight of the nine feet nine inches column of water; such force would accelerate the motion of the tank, until the velocity of the tank and the velocity of the rushing water were equal, minus the resistance of the air and the friction caused by the motion of the tank. The nature of this power would be simply pressure, acting inside the tank, immediately opposite the six-inch aperture, as exemplified by Dr. Barker's mill, which proves that the flowing jets give a force to turn it round, equal to the weight of a column of water whose base is as the size of the apertures, and their altitude as the head of

water above the apertures; independently of the medium in which the force of the jets is expended, and that the same result would take place in vacuo as in air.

If any persons should dispute this theory, and we asked them to explain the cause of the water flowing from the aperture in the tank, they would doubtless readily admit, that it was entirely the pressure of the water above the aperture, and so far we should be agreed; but they might demur to the statement, that a force equal to the weight of the column of water above the aperture, acted with the same direct force upon the tank inside and immediately opposite the aperture, to propel or move the tank in the opposite direction to the flowing stream. In order to satisfy all such as to the correctness of this hypothesis, we would recommend to them a very simple experiment. Let them furnish themselves with a small tank, having an aperture on one side near the bottom and another aperture, of equal capacity and shape, on the opposite side of the tank and on the same level; and let the tank be also constructed to run very easily on wheels. Then let them fasten to it one end of a cord, passing the other end over a pulley and attaching a weight thereto, for the purpose of ascertaining the actual amount of moving power. Then stop up one aperture with a plug fitted in water-tight, and let the tank be filled with water, while the opposite aperture is left open, and they

will find that the tank will be moved in the manner and with a force such as we have described; let them then take out the water-tight plug before mentioned, so that the water may be allowed to flow from both apertures, and it will be found that the tank will have no motion. This experiment might correct the mistaken notion which such persons entertain upon this subject.

These remarks apply with equal pertinence to the case of a vessel, as the actuating cause of the moving force is identical in both instances.

3rd. Paddle-wheels illustrate fully the mode in which water does, by reaction, communicate the power impressed upon it. The paddles act upon the water, and—according to the third law of Matter and Motion—reaction is always equal to action, and in contrary directions; consequently the water reacts upon the paddles, with a force equal to that with which the paddles act upon the water.

In none of these three modes of exerting power, is any loss attributed to the instability of water.

We will now bring under consideration the various propelling agents in present use in steam vessels; and in judging of their efficiency, shall examine them by the natural laws to which they are respectively subject, in every detail, and will begin with paddle-wheels.

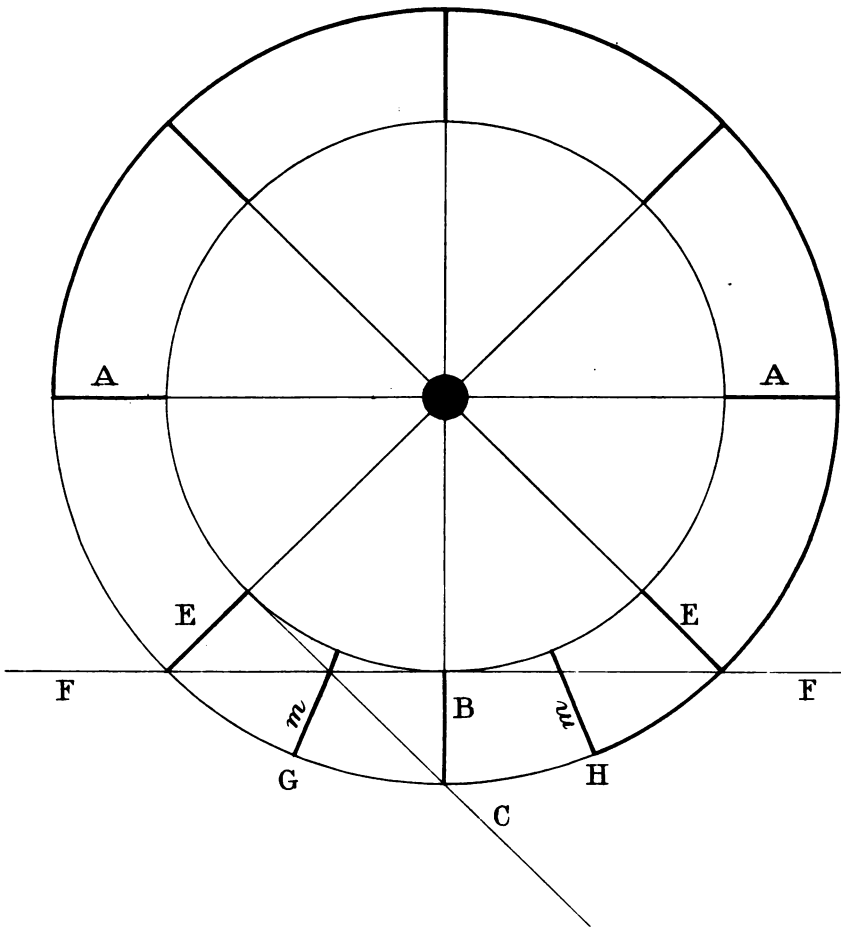
Persons who have not studied the subject thoroughly, have the impression that the effect of the power exerted by paddle-wheels is felt by the

vessel directly at the paddles, as they act upon the water: this, however, is an error that can be proved in many ways; perhaps one may suffice on the present occasion. Suppose a paddle forced down into the water from the side of a vessel, by means of a rack and pinion, in a direction perpendicular to the line of the vessel's draught of water: in that case, the vessel would be simply lifted, by the reaction of the water against the paddle, answering to the quantity of power exerted in pressing the water down, with a tendency to turn the vessel over; but if the top bearing, which holds the pinion shaft in its place, were not made fast, it would give way and the paddle could not be forced down. Hence the power exerted in pressing the paddle down, communicates the reaction of the water to the top bearing of the pinion shaft, and at that particular place only would the vessel be acted upon. In like manner, the reaction produced by the power exerted by paddle-wheels is felt by the vessel, only at the shaft bearings, in a direction at right angles to the plane in which the paddles act upon the water; and if the paddle shaft was not kept relatively fixed to the vessel by the bearings, the wheels would roll along the plane on which they rested and soon roll off the vessel; while no effect would be given to propel, over and above the friction produced by the weight of the wheels and shaft rolling, which would act upon the vessel in a contrary direction to the rolling motion; but the

amount of this friction, would hardly be sensible in giving motion to the vessel. It should be noticed here, that as the power communicated by the reaction of the water acts upon the vessel at the bearings of the paddle-shaft and the bearings are more or less above the water-line of the vessel according to the diameter of the wheels, a loss of power takes place; because the pressure upon the vessel would act at an angle more or less obtuse to the line of the vessel's centre of gravity; this loss of power would not, however, be very considerable, but still it should be noticed as a loss.

Next we bring under consideration the question, as to what rule should be observed in the construction of paddle-wheels, so as to render their agency most effective; that is to say, for a wheel of given diameter and depth of paddle, is there any law to determine the number of paddles for producing the greatest effect? We consider that there is, as may appear in diagrams 1 and 2. Suppose, in diagram 1, A A represents the diameter of the wheel, and B the supposed depth of paddle and also the depth of emersion, as seen by the line F F; then—according to the theory herein propounded—the number will be eight, because the whole quantity of water acted upon by each of the paddles would be moved away in the same line as the direction of the power impressed, without interfering with the preceding paddle, as seen in the line C. This may be further illustrated by diagram 2, in which A A represents

DIAGRAM. I.



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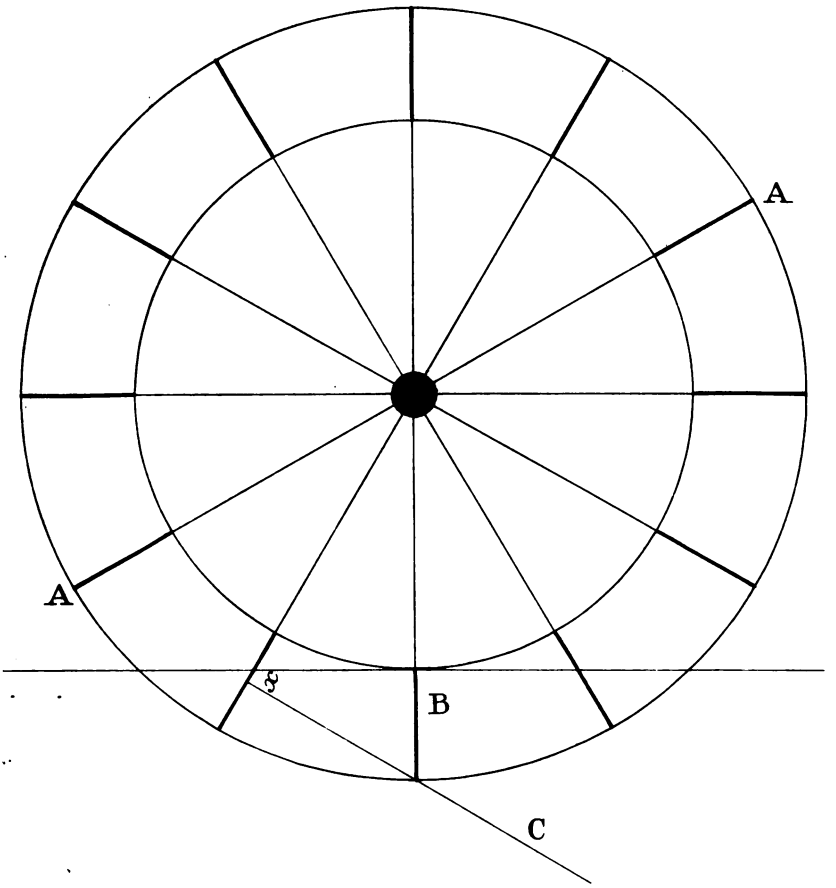

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the diameter of the wheel, and B the depth of the paddle immersed; and in which the number of the paddles is arbitrarily determined to be twelve. In this case it will be seen, that the whole quantity of water acted upon, cannot escape from the paddles in the direction of the power impressed, but part of the water acted upon represented by x, will follow the wake of the preceding paddle, as seen by the line C, and escape endways, or be turned over as the paddle rises out of the water; consequently a great part of the water represented by x becomes ineffective to propel the vessel, and may be considered as loss of power.

We will now examine the effect of the paddles when in motion, as represented in diagram 1, which we consider to have the best depth and number of paddles for a given diameter wheel. The paddle E enters at an angle to the surface of the water, when the tendency is partially to lift the vessel, as well as to urge it forward; and as the paddles pass the vertical position in leaving the water, they have a like tendency to depress the vessel, and the power thus expended in lifting and depressing, is lost for the purpose of propelling. The reasoning herein adduced is on the supposition, that the paddles are acting in still water. It may with propriety be asked, what portion of the whole power is rendered ineffectual to propel? this we will answer, by supposing the wheel in diagram 1 immersed to the depth of the paddle

represented by the line F F, and the wheel put in motion; the paddle B, being in its vertical position, receives a reaction from the water, equal to the quantity of surface and velocity with which the paddle acts upon the water; and the direction of the reaction being at right angles to the plane of the paddle, which at that instant is in the line perpendicular to the vessel's draught, it has its maximum or full effect, while the paddles E E are out of the water and have no effect. If we suppose the paddles E E to be in the position of G H, they will both at that instant act upon the water at an angle to the line of the vessel's draught, and upon a quantity only equal to *m*. It should be observed, that the two paddles in the position G H, are equal in propelling effect to the paddle B, when in a vertical position, and no more, as can be mathematically proved; so that, in estimating the loss of power resulting from the ever-varying angular action of the paddles, we have but to find the difference between the power necessary to give the paddle B, in its vertical position, a given velocity and the power necessary to give the same velocity to the paddles E E, in the position of G H; and this difference may, for all practical purposes, be estimated at three-eighths of the whole power exerted upon the wheels; because, if we suppose the acting surface of the vertical paddle to be 5, the effective acting surfaces of the two paddles E E will be a little more than 8.

There is also another cause which operates as a loss of power in the use of paddle-wheels, viz. the resistance of the air to those paddles moving out of the water; and not only is all the power necessary to overcome the resistance of the air entirely lost, but a great part of that power is exerted against the motion of the vessel; for as the part of the wheel immersed acts to propel the vessel forward, just so much of the upper part of the wheel is acting upon the air in the opposite direction, which has the tendency to repel the vessel thus doubling the quantity of momentum lost, for if the power thus exerted were neither for nor against the vessel's motion, it would be a simple loss of momentum; but when employed against the motion of the vessel, an equal quantity of power must be exerted in an opposite direction, to balance or neutralise the effect thus produced, which makes this particular amount of loss double. It should also be noticed, that the irregularity of the quantity of resistance offered to the paddles at sea in stormy weather, is considerable; the paddles at one moment being immersed far below their proper depth, bringing the engines almost to a stand-still, and at the next moment being nearly out of the water, when the engines run away with undue velocity. The resistance offered by paddle-boxes to the wind, and the inconvenience of their over-hanging and top hamper, is too obvious to need comment.

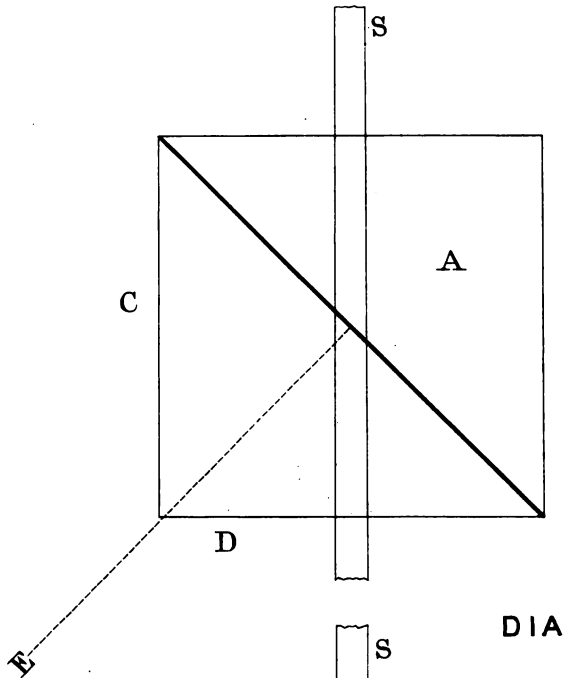
We have estimated that the power lost by the paddles acting constantly upon the water at various angles, more or less out of the line of proper direction, when in the best circumstances, that is, when the sea is quite calm, to be three-eighths of the whole power exerted; to which must be added, the power lost by the angular direction in which the paddle-shaft communicates the power of the engine to the vessel; also the loss occasioned by the paddles acting against the air; and the loss caused by the irregularity of the depth of water, which the paddles are subject to in bad weather. It may therefore be estimated, that the loss in employing paddle-wheels is one-half the power expended. To obviate some of the disadvantages of the paddles striking the water obliquely, the contrivance of feathering paddle-wheels has been adopted; but this plan is attended with complication of machinery, which is subject to derangement, and power is necessarily expended to retain the paddles in a vertical position; also the velocity of the paddles entering and leaving the water, is less than the paddle under the vertical line of the axis; and the lower part of that paddle describes a greater arc in its motion than the others, which is attended with disadvantage, inasmuch as the force being greater in the vertical line than in any other part, it has a great tendency to derange the machinery, and to repair this kind of wheel at sea, in stormy weather, is exceedingly difficult.

Let us now consider the mechanical action of the Screw, as a means of propelling vessels. It is a common impression, that the resistance of the water to the turning of the screw acts upon the vessel directly at the blades of the propeller; and that the propeller works itself through the water in the same way that a screw works itself into wood. Those who retain this notion frequently distinguish, from among different forms of screw-propellers, some as having very little slip, implying, that in others there may be much slip. This idea of the action of the screw upon water we consider to be quite erroneous, and shall endeavour to prove, that there cannot be any slip, in the ordinary sense of the term; and that the action of a screw into wood and the action of a screw-propeller in water, are not analogous. In the case of a screw turning into wood, if the wood gives way, the screw would, as it is technically termed, overturn, and make no progress; but in the screw-propeller, the water is constantly giving way by the least possible pressure; notwithstanding, the screw-propeller urges the vessel forward, in proportion to the velocity with which it is driven. These two cases are therefore very dissimilar, and we must adopt another theory to account for the progress of the vessel. The following appears to us the only theory by which the progressive motion of the vessel can be satisfactorily explained.

The screw-propeller is composed of two or more

portions of the blades of a screw, fixed upon a shaft, and placed in a line parallel to the keel and under the water-line of the vessel. As the surface of the blades stands at an angle to the axis of the shaft, they will, as the shaft revolves, act upon the water in which they are immersed obliquely, and the reaction, or pressure of the water upon the blades, will be also oblique, and the direction of the whole force of the reaction will be in a line perpendicular to the oblique surface of the blades. This force will be felt by the vessel, not at the place where the water reacts upon the surface of the blades, but at the end of the propeller-shaft, and there only will propelling force be given to the vessel; for if the shaft was not secured by the end bearings, the propeller would move back by the reaction of the water upon the blades, and the propelling effect would be lost upon the vessel. It should be observed, that the axis of the screw-propeller revolves in a direction across the line of the vessel's motion, and the blades act entirely immersed; and, although they act obliquely upon the water, their action is uniformly at the same angle, all round the circle in which they revolve. In these particulars, the screw-propeller differs materially from paddle-wheels, for the axis of the paddle-wheels revolves in the same direction as the line of the vessel's motion, and a paddle-wheel can only act with effect when it is partially immersed; also the position of the paddles is constantly varying, in the angular

DIAGRAM. 3.



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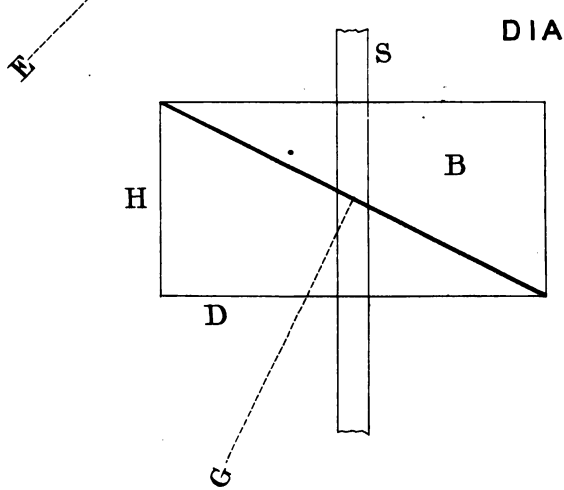

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direction of their action upon the water. It may further be observed, that the power of the screw-propeller is applied much nearer the vessel's centre of gravity; in this the screw-propeller has an advantage over paddle-wheels. In estimating the propelling force of the screw-propeller, the following rule may be adopted. Describe a square, and let the diagonal line, as in diagram 3, represent the angle at which the blades are fixed to the shaft S, and also their width. From this diagram we will endeavour to prove what quantity of power expended on the propeller is lost for purposes of propulsion. As the power expended upon the shaft will cause the blades, as they revolve, to act upon the water obliquely, it will be seen, by diagram 3, the direction of the action is as much lateral, or at right angles to the shaft, as it is in a direction parallel to the shaft's axis. In this diagram, the side of the square C represents the power lost and D the effective quantity of propelling power; the whole force therefore resolves itself in the direction of the dotted line E, and this angular direction of the force is the same all round the axis of motion, one half of the power acting, as already described, in a line parallel to the axis of the propeller, exerting a force to propel the vessel in the line of the keel, and the other half, at right angles to the direction of the keel, having no effect in propelling the vessel. If, however, the blades stand at a less angle or pitch, as in diagram 4, the line of direction of the whole power will in-

cline more to the axis, as the dotted line G does in diagram 4, when compared with the dotted line E in diagram 3. But although the reacting power of the water upon the screw, in this case, will more nearly coincide with the line of direct propulsion, the quantity of water acted upon will be less; as the line H, in diagram 4, is to the line C, in diagram 3. Assuming that the diameters of the propellers in diagrams 3 and 4—for brevity's sake called A and B—are the same, and the width of the blades and the angle or pitch in relation to the shaft such as is represented by the diagonals of the squares in the aforesaid diagrams, let it be supposed, that the mean circumference of each propeller is twenty feet; then the quantity of acting surface in the two propellers will be, respectively, as the line C in diagram 3, and the line H in diagram 4; which, if multiplied by twenty, will give the displacement of water by each propeller in every revolution, irrespective of their velocities. Thus it appears, that in each revolution of the two propellers, A will displace double the quantity of B. Now if a certain power, say 1,000, is given to the propeller A, it will exert that force upon a quantity of water represented by C in diagram 3, multiplied by two—supposing there are two blades—and acquire a velocity due to the quantity of water acted upon; and we will further assume, that the power of 1,000 exerted on the propeller A shall give a velocity of 100; if the same power is exerted on

the propeller B, in which the quantity of water acted upon in one turn is but half that of A, B will revolve with greater velocity, and which, by a law of fluids, will be one and a half the velocity of A; therefore, if A has a velocity of 100, with an acting surface equal to two, and B has a velocity of 150, with an acting surface of one, the amount of pressure in A and B will be equal. It now remains to be considered whether the propeller B has an advantage in propelling, over the propeller A, by having the dotted line of direction G in diagram 4 more inclined towards the axis than the dotted line E in diagram 3. We consider there is an advantage in favour of B, because the velocity of B is greater than that of A; and although B has no more pressure than A, the pressure of B will be effective for a longer time upon the vessel; that is to say, when the propeller A, with a given power, would cease to accelerate the vessel's speed, B would, with the same amount of power, continue longer to do so; consequently B would give more propelling effect than A.

In the foregoing remarks we have endeavoured to show, that the loss of power exerted by paddle-wheels is not less than one-half of the whole power, and, all things considered, there is, it appears, about the same loss of power in the employment of screw-propellers; for it must be observed, the screw-propellers are often but partially immersed, and, in bad weather, alternately in and out of the water.

This proportion of loss compared with the whole power exerted, is founded on the supposition, that the paddle-wheel and screw-propeller are constructed after the manner herein described, and which may be considered near enough, for all practical purposes, without going into minute mathematical analysis.

We have now to examine another distinct contrivance for propelling vessels, to which we particularly call attention; the principle having been, without due consideration, condemned by some persons, as has been already noticed. It will be sufficient for our present purpose, to take as an example, the means adopted in the Government gunboat, called the 'Waterwitch,' the propelling agent being volumes of water, discharged from the vessel aft, when the vessel is intended to go ahead, the direction of the volumes being reversed, when the vessel is intended to go astern. We shall make no comment upon the machine which gives the discharged volumes of water their momenta, for that will not affect the principle now under consideration, which is simply that relating only to the immediate agent of propulsion. In the case of the 'Waterwitch' this principle of propulsion—by means of discharged volumes of water—is substituted for paddle-wheels, or screw-propellers, and is, as we hope to prove, the simplest of all known agencies; for there is no complication whatever in the agent itself. It is also direct in its action, and

perfectly uniform; nor is there any loss of power whatever to be attributed to it, as we have shown there is in paddle-wheels and screw-propellers.

We have designated the power of propulsion in paddle-wheels to be that of reaction, because it is the reaction of the water, against which the paddles act, which causes propulsion; but the nature of the propelling agent employed in the 'Waterwitch,' is that of pressure, and not reaction—the pressure being similar, in the manner of its action, to that already shown by the illustration we have previously given, of a tank supplied with water, and in which, as we think, the true nature of this pressure is clearly exemplified. Assuming our illustration to be correct, it will follow, that if two volumes of water flow from a vessel in the same direction and with a certain velocity, we have but to calculate the areal capacity of the volumes of water and the altitude necessary to give that velocity, to know exactly the amount of force pressing to urge the vessel in a contrary direction to the flowing water. For example: suppose that the two volumes of water discharged from the 'Waterwitch' have each an areal capacity of twenty inches, and that the velocity with which they are discharged is as the velocity with which water would flow under a head of twenty feet; the pressure to urge the vessel forward would be as the weight of two columns of water, whose base is twenty inches diameter, and whose height is twenty

feet. This pressure would continue to accelerate the motion of the vessel, until the water in which the vessel floats offered a resistance to the motion of the vessel amounting to the pressure of a weight equal to the two columns of water already specified. The pressure would be felt inside the vessel, immediately opposite the outlets from which the water is discharged, and would receive no additional force from its being ejected into water, to what it would have if ejected into air, as may be proved by ocular demonstration.

We have referred to the 'Waterwitch,' because water is employed as the direct propelling agent, and the public have been made acquainted with the results of experiments, carefully carried out upon that vessel, in comparison with a vessel of like dimensions, fitted with screw propellers; but have purposely avoided any attempt to calculate what loss of power takes place in the apparatus by which the volumes of water are discharged, as such attempts might appear invidious, we having patented various plans on this principle before that adopted in the 'Waterwitch' was patented or made known, that is, more than thirty-six years ago, and proved, by actual experiment upon a small vessel worked by two small high-pressure engines—the propeller being only two feet six inches in diameter and eight inches deep, and which gave a speed of eleven miles per hour—that the mode of propulsion by volumes of water was perfectly efficient.

The observations we have made on this particular part of the subject have been simply to show that volumes of water employed as the immediate agent of propulsion are the simplest, and produce the greatest result for propelling vessels. The important question, as to the apparatus that should be employed for giving the greatest quantity of momentum to the volumes of water, with a given power, yet remains to be solved.

It has been already shown, that water in motion, whether used in the manner of repulsion, pressure, or reaction, in every case, if properly employed, gives a full and faithful result in driving machinery or propelling bodies, with a force equal to the quantity of motion contained in the moving water, and without any deduction or loss of power. Let us now inquire into the cause, why this mode of propulsion has not been brought into operation with at least as much success as has been achieved by either paddle-wheels or screw-propellers. The cause, we affirm, is not to be attributed in any degree to the inefficiency of water, but to the inefficiency of the means used in communicating the power of the engines to the volumes of discharged water, for if there was no loss in the plan or means used in communicating the power of the first mover, the momentum of the volumes of water would be equal to the power of the engine; hence the defect, or loss of power, is to be found, not in the principle of water as an agent, but in

the apparatus used failing to give a momentum to the volumes of water equal to the power of the first mover. If it should be said that we are not justified in comparing volumes of water to paddle-wheels or screw-propellers as immediate agents of propulsion, we would reply, that the moving water, to which we have referred, when considered as an agent for propelling vessels, is in reality only a substitute for paddle-wheels or screw-propellers, and therefore we are justified in the comparison. The only difference between them is, that a loss of power is to be attributed to the paddle-wheels or screw-propellers, which cannot be attributed to the volumes of discharged water.

We have thus endeavoured to demonstrate that the objections entertained by those who contend that water discharged in water, for the purpose of propelling vessels, is radically bad in principle, are altogether futile, and that their reasonings are contrary to fact. Before, however, coming to the conclusion, that volumes of water can be employed with greater efficiency in propelling vessels than either paddle-wheels or screw-propellers, it would have to be shown that a simple apparatus can be constructed for maintaining a constant discharge of water, whose momentum would be greater, with a given power, than the propelling force of paddle-wheels or screw-propellers. This part of the subject will require the most attentive consideration, because what remains to be advanced constitutes

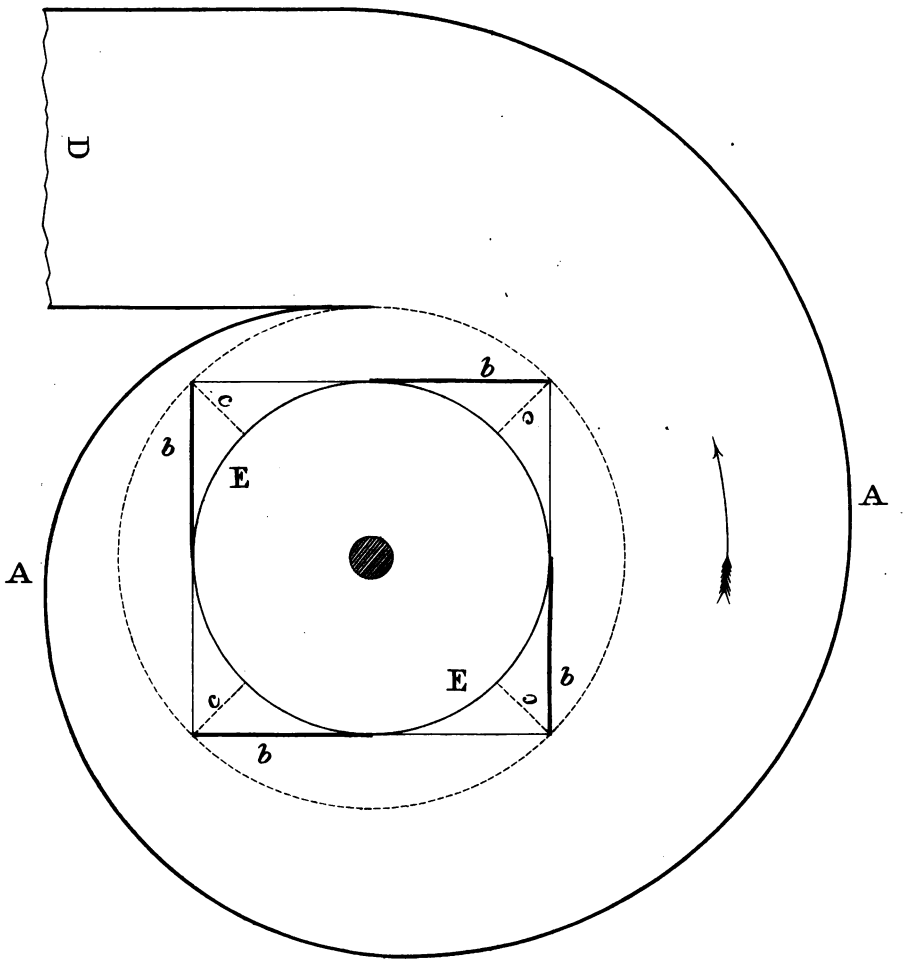
the premises from which our conclusions are deduced. We shall endeavour not to omit any essential point that is necessary to be considered, in order that it may be clearly ascertained whether those conclusions are perfectly consistent with the natural laws of mechanics.

We will first state what is mechanically required of a machine that would be able to accomplish this desideratum. It would require to be continuous and uniform in its motion, and that the whole quantity of water acted upon should be immediately expelled, without any tortuous motion, in a rectilinear direction; also, that the direction of the water supplied to the machine should be in the same line as that of the discharge—after the manner that paddle-wheels receive a constant supply of water while they are in action. It would further be required, that the arrangement should be entirely free from complication. Such a machine would, doubtless, be perfect of its kind. To be continuous and uniform in action, the moving force of the machine, it would appear, must be rotary: supposing it to be so, we must not omit to notice that motion given by rotary action naturally takes tangential directions from the plane or point of impact; and that, as there are an indefinite number of tangents in an entire circle—each one standing at an angle to the others—the whole force expended upon a rotary mover, when entirely immersed, would be diffused upon the water in an indefinite number of

directions—one-half of which has opposite directions to the other half, and the whole quantity of rotary motion, except that of the screw, has a neutralising effect; so that the required machine must, by some artful arrangement, be constructed to supersede the tangential action without loss of power; that is, the entire quantity of the acting surface of the propeller must expend its force in a manner that shall give to the whole quantity of water acted upon a rectilinear direction, without having any rotary motion, and thereby render the volumes of water discharged perfectly available for propelling by direct action. A machine of this kind it is intended to submit to the public; and this is the chief end of the present treatise.

It may not be out of place to state that, more than thirty years ago, we attempted to carry this idea into effect; and, as an explanation of the manner by which we endeavoured to accomplish the object may help to make manifest the superiority of the machine about to be introduced, we will give a brief description of the apparatus which we patented, in the year 1831, as an improvement in propelling vessels. It consisted of a rotary propeller, revolving in a volute box, as is represented in diagram 5. A A represents the volute box in which the propeller revolved; the propeller, consisting of four straight planes, *b*, *b*, *b*, *b*, each one-half the length of one side of the square plate to which they were made fast, and in the centre of which

DIAGRAM. 5.



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the driving shaft was fixed. The eccentricity of the side of the box was as the measure of the acting surfaces contained in the four planes of the propeller, represented by the dotted lines *c*, *c*, *c*, *c*; this space, marked D, was left open for the exit of the water acted upon by the propeller, and the admission or ingress aperture was formed within the acting circle of the propeller or dead centre EE. Now, if steam or any other power be given to the propeller, as above described—it being left perfectly free to move in the direction of the arrow—it would act on the water in the box, and acquire a velocity which, if multiplied into the quantity of acting surface contained in the four planes, would give a momentum to the water in the box equal to the power exerted on the propeller.

It was supposed that an equal quantity of water would be continually discharged in a straight line from the aperture D, and that the force of this stream would be available to propel a vessel without loss of power, or nearly so. Now, although the velocity of water acted upon in the box was supposed to be equal to the mean velocity of the propeller, the loss which ensued from the water being compelled to move in a curved line, during every revolution of the propeller, had to be deducted, because its natural tendency was to fly off immediately from the propeller, in an indefinite number of tangents, and this constraining influence must therefore have the effect of retarding the

velocity of the propeller to the extent of the power necessary to compel the water to take a curvilinear direction; and as the volute side of the box is a much longer line than the mean circumference of the propeller, the water in its motion from the propeller must accommodate itself to the extended circumference of the volute box, which would give to every particle of the water an unnatural and tortuous motion. We must also notice that the box was supplied with water in a direction perpendicular to the direction acted upon, which is also a constrained and unnatural direction, and consequently attended with loss of power.

It is most difficult to calculate the entire loss of power resulting from the causes enumerated, because very many and various experiments would have to be made in order to furnish a datum: suffice it to say, that the loss must be considerable; yet, notwithstanding these defects, it was from this plan that we obtained a speed of eleven miles per hour in a boat, as has been already stated.

The invention we are now about to submit for public consideration and adoption, is so unique, with respect to its construction and the effects it produces, as to deserve close investigation. It consists of a rotary propeller, composed of two blades, each standing in the position of right angles to the other, and affixed at an angle of forty-five degrees to the shaft, by which they are made to revolve, the two blades constituting the

whole quantity of acting surface. If the propeller is cast in metal, the pattern may be made in the following manner; that is to say, turn in wood, to the size required, a double cone, the sides being quarter-circle curves, and the height of each cone being equal to the radius of the base; then, if the double cone is cut in two, in a straight line from one apex to the other, by moving one part a quarter of a circle round and bringing the two parts in contact with each other, the bases of the divided double cone will, at each end of the semicircle, terminate at the apex of the opposite half double cone, and if secured in that position will form the said two-bladed propeller. This propeller revolves in a box formed from a circular tube of the same internal diameter as the outer diameter of the propeller, and in length equal to the diameter. The tube is divided longitudinally into two equal parts, and affixed together, at right angles to each other, with a partition or diaphragm between the half tubes; thereby forming two half-round channel ways with their ends open, and making four semicircular apertures in the box. The shaft of the propeller works in the plane of the diaphragm, and in the diagonal line of the square formed by the crossing of the two half tubes. In the centre of the diaphragm there is an aperture, of a shape and size sufficient only for the propeller to revolve in without touching the edges of the aperture. Suppose the machine,

as described, to be fixed inside a vessel, near the bottom, with the shaft over the keel, and also in a line fore and aft with the keel: then the two discharging apertures will be in a direction towards the stern of the vessel, and the two admission apertures towards the bows; they would not, however, be in a line parallel with the keel, but at an angle of forty-five degrees on either side of the keel.

Having given a brief description of the machine, and the position in which it is placed in a vessel, we will now attempt to explain its action, and point out the peculiarities of the machine and the assumed advantages it possesses over paddle-wheels and screw-propellers.

Suppose, then, the machine fixed in a vessel as described, and a given power exerted upon the shaft, for giving rotation to the propeller. It is stated, that the surfaces of the two blades contain the whole quantity of acting surface of the propeller, and that, separately, they stand in the position of right angles to each other; also, that the shaft or axis of motion is affixed thereto between the two blades, that is, at forty-five degrees to the surface of each blade: now, as the natural direction of the motion of the water, given by the blades when in action, coincides with the line in which the half tubes that form the channel ways are arranged in position with the propeller; and also, as the channel ways are equal in areal capacity to the acting surface of each blade of the propeller, the whole

quantity of water acted upon has a free and direct passage through the machine in a natural direction, without having any rotation. It consequently follows, that the momenta of the two streams are equal to the quantity of acting force exerted by the two blades; for it must be noticed, that the supply of water into the box, to receive the constant action of the propeller, is in the same line of direction as that of the discharge; so that there is no loss of power in obtaining a full supply of water, any more than there is in supplying water for the paddles of a paddle-wheel. If the streams of water were in the same line, or parallel to the keel, the propelling power would be equivalent to the power expended; but as the direction of the streams is at an angle of forty-five degrees to the keel, the streams have to be turned one-eighth of a circle, in order to be discharged in the best line of direction for propelling the vessel, that is, parallel to the keel. The loss of power resulting from this necessity, it may be contended, is far less than the loss attending the use of paddle-wheels or screw-propellers. It may also be stated, that the weight of paddle-wheels and the shaft by which they are driven is very great; and the weight of a screw-propeller, including the long shaft that drives it, is also very great, necessitating considerable power to overcome their friction when in motion; whereas the propeller herein proposed to supersede these ponderous machines is less than one-tenth of their

weight. We will however endeavour, without partiality, to bring in review the mechanical causes that operate in this machine, to reduce the power of the first mover, and consequently render it unable to give its whole power to propel the vessel. We have shown that the direction of the discharged volumes of water is at an angle of forty-five degrees to the true line of direction, that is, parallel to the keel; therefore a certain quantity of power must be deducted and considered as loss—sufficient at least to turn the direction of the streams discharged from the machine, one-eighth of a circle, both to the admission and from the discharging apertures: if the channel ways, however, are not contracted, but made of the same form and capacity as the channel ways in the box, the loss cannot be very considerable. It is admitted that the actual loss of power can only be ascertained by experiment; we however imagine it to be in the proportion of the difference between the length of one-eighth of the circumference of a circle and the chord of that segment. This proportion of loss will, it is considered, be sufficient to allow for turning the streams from the apertures of the box, into the true direction for giving propelling effect. If it should be said, that some power should also be deducted on account of the propeller working in the box, we may state in reply, that we have made an experiment with a propeller as described, of three inches diameter, put in motion by weights over a

pulley, in which it was ascertained that the propeller, when immersed three inches under the water and out of the box, made the same number of revolutions with the same weights, and that the weights ran down the same distance, in the same time, and no more, than it did when revolving in the box; this was proved by different weights. From this fact, it is concluded, no deduction need be made on account of the propeller working in the box, and this is explained by the water being discharged instantaneously, when it is acted upon in the same straight line, without any change of motion; but supposing that the streams are conducted under the bottom of the vessel, which is perhaps better than at the sides, some deduction would have to be made on this account; we will therefore allow one quarter of the power of the engines to be subtracted, and this, we consider, will be more than sufficient to provide for all losses that this machine would be subject to. Upon this calculation the new system would lose but one-half the power lost in the employment of paddle-wheels or screw-propellers.

Other important advantages would be attained in the adoption of this machine, from its being entirely within the vessel, below the water-line. As for example: it is not subject to derangement from a heavy sea, and is perfectly uniform in action, without having any tremulous motion; nor is it subject to any of those casualties, which paddle-

wheels and screw-propellers are liable to meet with, especially in stormy weather.

The peculiarities of this machine are: first, that although the action of the propeller is rotatory and perfectly immersed in water, the whole effect of the action is rectilinear. Second, a perfect supply of water is obtained in the natural line of direction, that is, in the same rectilinear line as the water is expelled from the propeller. Third, that the direction of the acting surfaces of the moving power of the machine is given to the water in the same angle towards one end of the axis of motion, both above and below the axis. These peculiarities belong, we believe, exclusively to this machine. It should be added that various modifications may be made in the machine, which we have not attempted to describe, as they would all be constructed on the same principle. The variations consist in the shape of the box: as for example, instead of being formed from a cylinder, it may be formed of a rectangular figure; and in that case the propeller would consist of two or more portions of a screw, the pitch being such as would present their acting surface on the upper and lower side of the shaft in the direct line of the rectangular channel ways, and the aperture in the diaphragm formed to suit the spiral blades of the propeller; while, to avoid any end pressure being given to the shaft by the action of the spiral blades, a cone should be fixed upon the shaft at each end of the blades; the bases of the cones being

the same diameter as the propeller and affixed to the shaft, with their apexes towards each other. The spiral blades would terminate in twisting round the cones.

We have now endeavoured briefly, but in as clear and popular a way as possible to explain the principles on which steam vessels are propelled, both in the cases of paddle-wheels and screw-propellers, and also by the agency of discharged volumes of water; and we trust that what has been advanced will be considered of sufficient importance to repay the time that may be devoted to the investigation of these pages; and that, after due consideration of the subject, the reader may admit the justness of the writer's reasoning; that the propelling of vessels, by the expulsion of volumes of water, as has been proposed, is superior to either paddle-wheels or screw propellers.

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